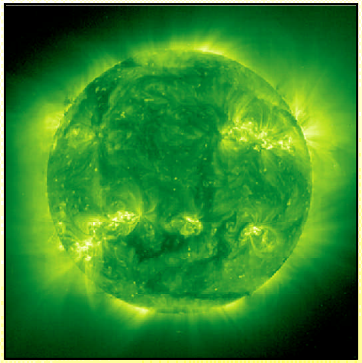
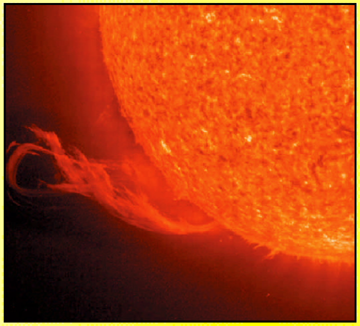
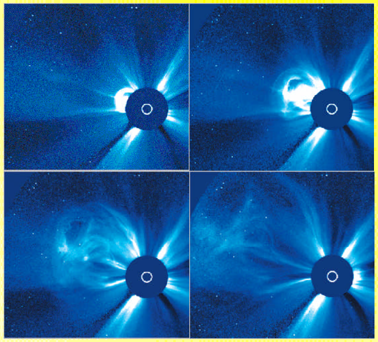
NEW VIEWS OF THE SUN



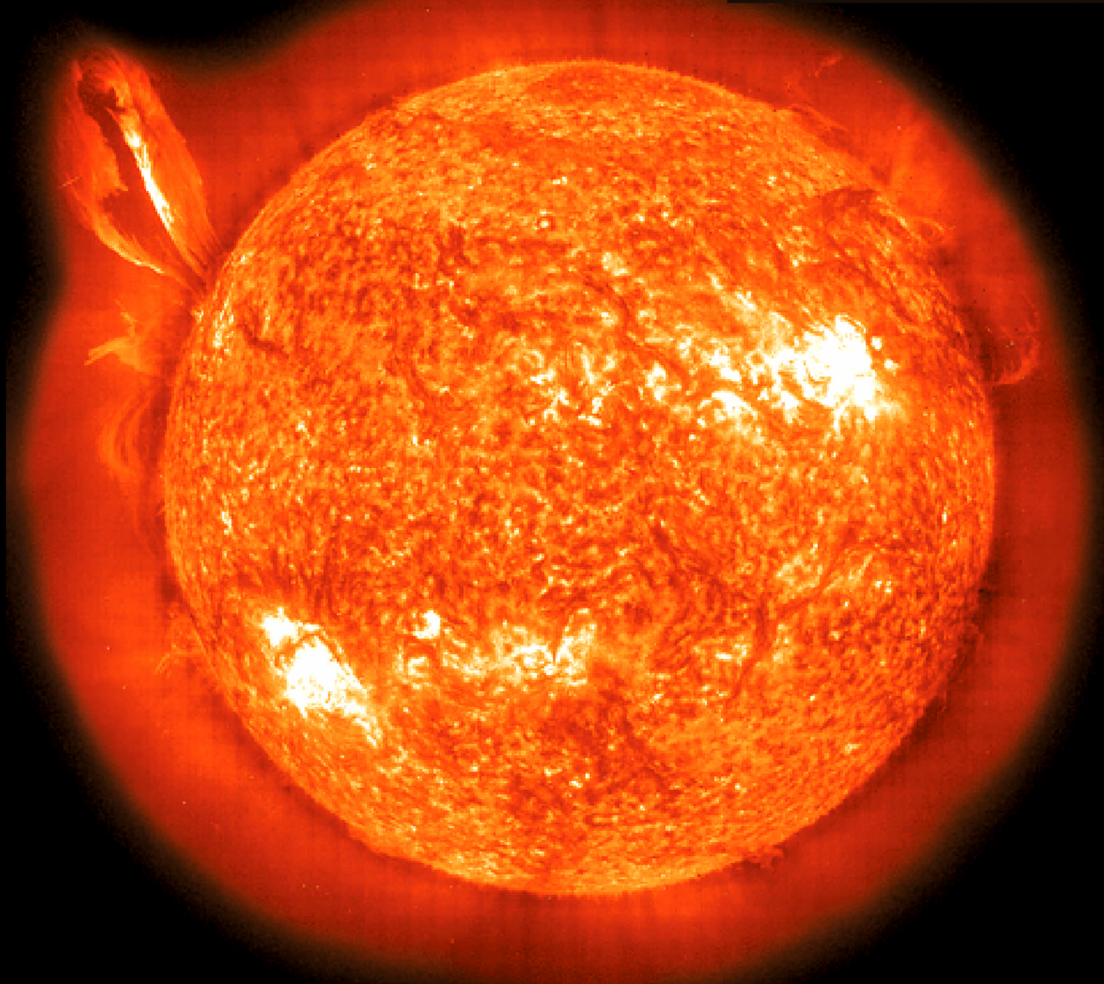
An image of the Sun taken in ultraviolet light reveals particles at 1.5 million degrees Celsius shaped by magnetic fields. Solar images like this, taken 24 hours each day for over several years, have provided scientists unparalleled opportunities for new solar research.



This close-up image of a large eruptive prominence emerging from the solar surface was taken in an extreme ultraviolet wavelength of ionized helium heated to about 60,000 to 80,000 degrees K .



A large Coronal Mass Ejection (CME) as recorded by SOHO in August 1999. CMEs are clouds of million degree C gases ejected out from the Sun at hundreds of km per second. The CME is visible because the bright light of the solar disk has been blocked. The white circle in its center shows the size and location of the Sun. The sequence covers about six hours.



This image of the Sun's lower corona, taken in an extreme ultraviolet wavelength of ionized helium heated to about 60,000 to 80,000 degrees K, shows a large eruptive prominence that has emerged from the solar surface. It was taken in 1999 by the Extreme ultraviolet Imaging Telescope on board the SOHO (Solar and Heliospheric Observatory) spacecraft.

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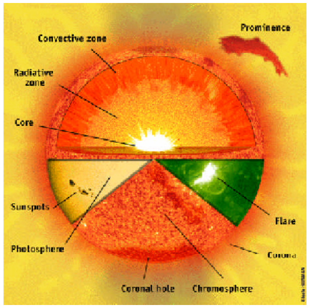
NP-2000-1D-121-GSFC

SOHO Illuminates the Sun

The closest star to Earth, 150,000,000 km (93 million miles) away, the Sun produces the energy that drives our ecosystem, making it the source of all life on Earth. The Sun is a ball of plasma (super heated gases) seething and moving at extreme temperatures. It produces the **solar wind,** a stream of million degree gases which flows out from the Sun at hundreds of kilometers a second. The solar wind interacts with Earth's magnetic field to produce the awe inspiring aurora (also known as the Northern or Southern lights). Solar wind disturbances can also disrupt communication signals and cause power outages. If we could detect and understand the sources of the solar wind, we could prepare for and reduce its negative effects.

The **Solar and Heliospheric Observatory** (SOHO), launched in late 1995, is a spacecraft that is increasing our understanding of the Sun and solar wind. It was designed to explore a number of questions:



This drawing shows the major features of the Sun. The Sun actually consists of 90% hydrogen and a mixture of other gases. In diameter, it is over 100 times bigger than the Earth.

What is it like inside the Sun?

Hot? No question there: but just how hot is it? We think that the core of the Sun is a 15 million degree C soup of electrons and protons stripped from the hydrogen atoms that make up 90 percent of the Sun. Every second, thousands of protons in the Sun's core collide with other protons to produce helium nuclei in a fusion reaction that releases energy. Just outside the core, energy moves outward via radiation. Closer to the surface, the energy moves out via convection - hot gases rise, cool, and sink back down again.

As these masses of gas move, they push off of each other causing "Sun-quakes." These make the material in the Sun vibrate or, "ring like a bell," at certain harmonic frequencies. The study of the movement of the Sun's surface is called helioseismology (as the study of movements of Earth's surface is called, simply, "seismology"). Helioseismology helps us determine the Sun's internal structure, the temperatures, densities, proportions of different elements, and the processes occurring at different locations underneath the Sun's surface. Dopplergrams (see image to the right) can detect and identify the various internal sound waves the Sun produces.

Why is the corona so hot?

The layer of the Sun's atmosphere we usually see in visible wavelengths of light is called the **photosphere**. The photosphere is at about 5500° C. The **corona** is the outermost layer outside the Sun's atmosphere. Scientists would expect that the Sun would be cooler farther from the heat source in the core. However, this reasoning seems to break down when we look at the Sun's corona. The corona is over a million degrees C! Scientists do not know why.

From Earth, the corona is best seen during a solar eclipse. From space, however, we do not have to wait so long. Without the scattering of light by the Earth's atmosphere we can create an artificial eclipse using an instrument called a coronagraph. This blocks out the bright disk of the Sun with a corresponding black disc in the camera's center so that we can see and study the corona in visible light scattered off the coronal electrons *(see image in the section below).*

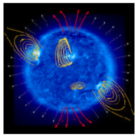
Because the corona is so hot, it also emits light in ultraviolet wavelengths. These wavelengths cannot get through the Earth's atmosphere, but we can see them using the SOHO satellite in space.

What accelerates the solar wind?

The corona is constantly expanding into space to form the solar wind. The solar wind particles flow out past the farthest planets to form the realm we call the **heliosphere**. Sometimes the wind blows out steadily, but at times the Sun ejects large magnetic field structures called Coronal Mass Ejections (CMEs). [*See the photo series on the other side*] When the material from CMEs reaches Earth, it can cause pretty effects like the aurora or potentially disruptive effects like power outages in cities near the magnetic poles.

How is the Sun's magnetic field created and structured?

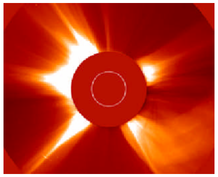
The Sun's magnetic field is generated by plasma motions below the Sun's surface and extends out to shape and control the solar atmosphere and the entire heliosphere. Understanding the magnetic field is key to understanding the solar wind, heating of the corona, and solar activity such as CMEs, sunspots, and flares. Solar activity increases and decreases in approximately an eleven year cycle. SOHO was launched during the activity minimum and its observations have shown that the Sun is much more active than expected during the solar minimum.



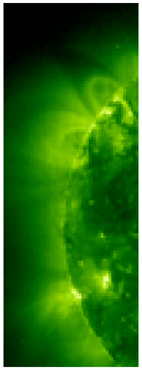
Magnetic field lines on the Sun

The Sun's Atmosphere

In these images of the corona we can see the effects of the magnetic field which shapes the Sun's atmosphere. The magnetic field creates the loops (below left) and other structures such as the ray-like plumes (below right) in the corona, as well as the sunspots we see in the photosphere. Scientists think the magnetic field is important to understanding coronal heating and the solar wind, but do not yet know exactly how.



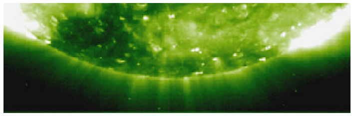
Visible light image from a coronagraph shows considerable activity in the Sun's corona



The ultraviolet image *(left)* shows **loops** in which the magnetic field can be seen circling back towards the Sun, trapping hot gas.

The corona is shown in visible light in the SOHO coronagraph image (right). A coronograph blocks out the light from the bright inner part of the Sun so that we can see its relatively faint corona. The bright circle in the center represents the location of the Sun's disk. This image from 1998 is fairly typical of the level of activity that is seen in the corona. The solar wind constantly carries particles away from the Sun into space at hundreds of thousands of mile per hour.

The ultraviolet image below reveals structures known as solar plumes, which extend from the polar regions out into the solar system. Hot gas flows along these structures into the solar wind.



Doing Your Own Investigation: Tracking Sunspots

All you need to begin this investigation is for someone to have web access. Using the scientific method, you will collect data, record observations, and evaluate your data to determine, or at least estimate, the Sun's rotation rate.

Sunspots are dark areas on the Sun's surface that indicate concentrations of magnetic activity. To start your sunspot observations right away, pick up your solar data for the last 2 weeks or so, rather than collecting data from today forward, though that is another option. Your "eyes" will be the SOHO spacecraft, currently observing the Sun about 1,000,000 miles from Earth. Using daily pictures collected by the SOHO spacecraft, you are going to observe and record information about the currently visible sunspot groups.

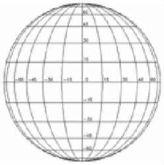
MDI intensitygram image of sunspots

The pictures are kept online for several months. You can access previous images easily by going to the SOHO images page for today's date and hitting the "PREVIOUS" key for each day in the past you want. Go to: **http://sohowww.nascom.nasa.gov/data/latestimages.html.** If you do not have access to these images in the classroom, perhaps one person could do the collecting, print them out, and then make copies for the others.

To observe and track the movement of sunspots (actually, magnetically "active regions") across the Sun's visible disk, you will want to use the "Intensitygram images" because they show sunspots the best.

Each image indicates the time which it was taken (e.g., SOHO MDI: Intensitygram, full disk, at 09:52 UT). The "9:52" is the time. For each day, try to get an image from about the same time as the day before. Measure only the large blotches. When you measure the latitude and longitude of your sunspots, mark the center of the spot group.

Print out a copy of each day's internet solar image. (The real-time images include a white square in the center of the Sun which you can ignore.) You want to map where the sunspot groups appear. In order to better judge sunspot positions, you might want to use a Latitude/Longitude grid. You can get one and print it from **http://solar-center.stanford.edu/images/sungrid-0.gif**. You may have to adjust it with an enlarging copier to make it match the size of your solar images. And it will be easiest if you can make into a transparency. You can lay this over the images to gauge the sunspot positions. If you don't have printed images, just sketch the image and sunspot groups you see. And if you sketch, try placing the latitude/longitude grid directly over the image on your screen to help measure exactly where to sketch your spots.



Solar Longitude/Latitude grid

For each of the major sunspots groups, for each day record on a sunspot recording worksheet:

- The name of each spot group. Make up any name, but make sure to keep track of which group has which name.
- Where (i.e., at what latitude and longitude) the spot groups lie
- Note whether there were any observable changes in your sunspot groups (has the group changed size, shape, disappeared altogether?)

You have now gathered and recorded your data. After you've tracked the progress of your images across the Sun, you should be able to estimate when sunspot groups or active regions will disappear behind the Sun's limb (the edge). Note that because the Earth is also moving around the Sun in the same direction at about 1 degree a day, you need to add one percent to the computed apparent daily motion to compensate for this.

Looking at the earliest of your data sheets, pick a particular sunspot group or active region which is soon destined to go around the Sun's right edge. Can you guess when that group will disappear around the limb? Do you think it will reappear again on the left limb, after it has crossed the backside of the disk? Now, continue to check the daily solar images until you see your spot groups disappear or reappear. How long did it take?

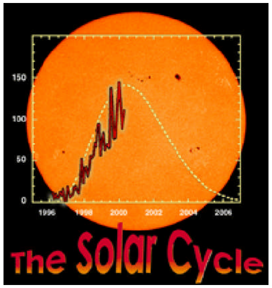
If a region or group failed to reappear from the back side of the Sun, what do you think happened to it? Can you suggest how long different active regions last?

This kind of observing, recording, and evaluating the data is exactly how an astronomer named Christof Sheiner determined over 300 years ago that sunspots moved around the Sun at a fixed rate.

Credit and thanks to the Stanford SOLAR Center for this exercise.

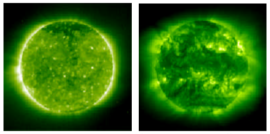
Sunspots and the Solar Cycle

Every 11 years, the sun reaches a peak period of activity called "solar maximum," followed a few years later by a period of quiet called "solar minimum". During solar maximum, there are many sunspots, solar flares, and coronal mass ejections, all of which can affect communications and other technology here on Earth. During solar maximum there are can be hundreds of sunspots, and during solar minimum perhaps only a dozen can be found. The plot at right shows the number of sunspots since 1996, about the last minimum, to early 2000. The last maximum occurred around 1989, and the current one should peak sometime in mid- 2000 or 2001.



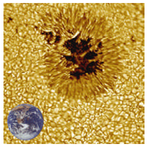
One way to track solar activity is by observing sunspots. Sunspots are relatively cool areas that appear as dark blemishes on the face of the sun. They are formed when magnetic field lines just below the Sun's surface become twisted and poke though the solar photosphere. Sunspots can last from a few hours to several months, and a large sunspot can grow to several times the size of Earth *(see image below)*. Though the Chinese recorded some observations as early as 28 B.C., scientists have been observing and recording sunspots since the 17th Century.

Why do scientists care about sunspots? Because they are visible signs of the turmoil inside the Sun that lead to space weather effects on Earth. Coronal mass ejections (CMEs) and solar flares are often associated with sunspot groups. The twisted magnetic field above sunspots are sites where solar flares are frequently observed to occur. Solar flares are short, intense explosions that accelerate high-energy particles and radiation into space. CMEs, caused by temporary breaks in the magnetic controlling field lines, are much larger storms that thrust *billions* of tons of particles at *millions* of miles an hour. During solar maximum CMEs and flares can occur several times a day with some of those storms aimed in the Earth's direction. Both can cause auroras on Earth (known in the northern hemisphere as Northern Lights), which from the ground appear as shimmering curtains and swirls of red and green light in the night sky.



Extreme ultraviolet images of the Sun reval the difference in solar activity levels from 1996 to 2000.

The energy from these solar blasts can disrupt radio communications, upset electrical power systems, damage satellites and change thier orbits, and cause navigational equipment to make mistakes. Astronauts walking in space can be endangered by radiation from these events.



A sunspot compared to Earth

Fortunately, our planet is protected from the harmful effects of the radiation and hot plasma by our atmosphere and by an invisible magnetic shell known as the magnetosphere. Produced as a result of Earth's own magnetic field, the magnetosphere shields us from most of the Sun's particles by deflecting them around the Earth. We are also protected by the many spacecraft, telescopes, and scientists who monitor space weather in order to provide warnings for those of us on Earth.

Long-term cycles of solar activity also may have an impact on Earth's climate. Scientists are currently debating whether some of the lesser ice ages on Earth were related to unusually long periods when the Sun had few sunspots.

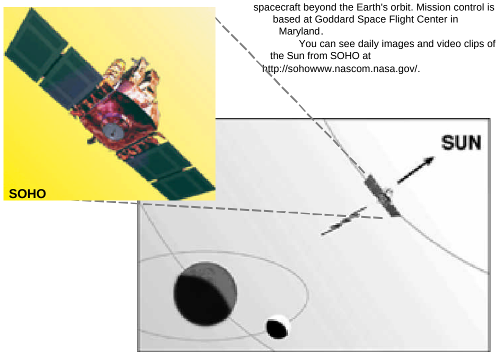
Solar and Heliospheric Observatory (SOHO)

The Solar and Heliospheric Observatory (SOHO), is a sophisticated spacecraft built and run by the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA). Many other institutions in the U.S. and Europe were involved with the development, testing, and operation of the 12 instruments on board. SOHO, launched in December 1995, should continue to observe the Sun and the solar wind for years to come.

SOHO has been one of ESA and NASA's most ambitious astronomy projects. In sending back a wide range of unprecedented images and data, SOHO is helping us understand the interactions between the Sun and the Earth's environment better than has been possible to date. It has already provided scientists with critical information in their efforts to solve some of the most perplexing riddles about the Sun, including the physical conditions of the solar interior, the heating of the solar corona, and the acceleration of the solar wind. It is giving solar physicists their first long-term, uninterrupted view of the mysterious star that we call the Sun.

That view of the Sun is achieved by operating SOHO from a permanent vantage point 1.6 million kilometers (900,000 miles) toward the Sun in an orbit near the first Lagrangian point (L_1), where the Sun's and Earth's gravitational forces are in balance. This location offers a new advantage: most previous solar observatories orbited the Earth, which caused observations to be periodically interrupted when our planet 'eclipsed' the Sun. SOHO watches the Sun 24 hours a day. Large radio dishes around the world, which form NASA's Deep Space Network, are used to track the spacecraft beyond the Earth's orbit. Mission control is based at Goddard Space Flight Center in Maryland.

You can see daily images and video clips of the Sun from SOHO at http://sohowww.nascom.nasa.gov/.



The SOHO spacecraft (above) is shown with its solar panels extended. The 12 instruments on board gather data which tells us about the inside of the Sun, activity on the Sun's surface, the Sun's atmosphere, and its effects on Earth's environment. The illustration shows its position in orbit about 1.6 million kilometers (almost 1 million miles) sunward of the Earth.

NASA Resources for Educators

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue and an order form by one of the following methods:

- NASA CORE
  Lorain County Joint Vocational School
  15181 Route 58 South
  Oberlin, OH 44074
- Phone (216) 774-1051, Ext. 249 or 293
- Fax (216) 774-2144
- E-mail nasaco@leeca8.leeca.ohio.gov
- Home Page: http://spacelink.msfc.nasa.gov/CORE/

Educator Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educator Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Teachers may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Teacher Resource Center
Mail Stop 253-2
NASA Ames Research Center
Moffett Field, CA 94035-1000
Phone: (415) 604-3574

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Teacher Resource Laboratory
Mail Code 130.3
NASA Goddard Space Flight Center
Greenbelt, MD 20771-0001
Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
NASA Teacher Resource Room
Mail Code AP-2
NASA Johnson Space Center
2101 NASA Road One
Houston, TX 77058-3696
Phone: (713) 483-8696

FL, GA, PR, VI
NASA Educators Resource Laboratory
Mail Code ERL
NASA Kennedy Space Center
Kennedy Space Center, FL 32899-0001
Phone: (407) 867-4090

KY, NC, SC, VA, WV
Virginia Air and Space Museum
NASA Teacher Resource Center for
NASA Langley Research Center
600 Settler's Landing Road
Hampton, VA 23669-4033
Phone: (804) 727-0900 x 757

IL, IN, MI, MN, OH, WI
NASA Teacher Resource Center
Mail Stop 8-1
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135-3191
Phone: (216) 433-2017

AL, AR, IA, LA, MO,TN
U.S. Space and Rocket Center
NASA Teacher Resource Center for
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P.O. Box 070015
Huntsville, AL 35807-7015
Phone: (205) 544-5812

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NASA Teacher Resource Lab
Education Complex - Visitor Center
Building J-1
NASA Wallops Flight Facility
Wallops Island, VA 23337-5099
Phone: (757) 824-2297 / 2298

Regional Educator Resource Centers (RERCs) offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically via NASA Spacelink.

NASA On-line Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, accessing information about educational grants, interacting with other schools which are already on-line, and participating in on-line interactive projects, communicating with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page: http://www.hq.nasa.gov/office/codef/education/

or, for more information, send an e-mail to: comments@spacelink.msfc.nasa.gov

NASA Television (NTV) is the Agency's distribution system for live and taped programs. It offers the public a front-row seat for launches and missions, as well as informational and educational programming, historical documentaries, and updates on the latest developments in aeronautics and space science. NTV is transmitted on Spacenet 2 (a C-band satellite) on transponder 5, channel 9, 69 degrees west with horizontal polarization, frequency 3880 megahertz, audio on 6.8 megahertz; or through collaborating distance learning networks and local cable providers.

Apart from live mission coverage, regular NASA Television programming includes a News Video File from noon to 1:00 pm, a NASA History File from 1:00 to 2:00 pm, and an Education File from 2:00 to 3:00 pm (all times Eastern). This sequence is repeated at 3:00 pm, 6:00 pm, and 9:00 pm, Monday through Friday. The NTV Education File features programming for teachers and students on science, mathematics, and technology, including the *NASA. . .On the Cutting Edge* Education Satellite Videoconference Series. The videoconferences include NASA scientists, astronauts, and education specialists presenting aeronautics and Earth & space science topics of interest to teachers and students of grades 5-12. The series is free to registered educational institutions. The videoconferences and all NASA Television programming may be videotaped for later use.

For more information on NASA Television, contact:
NASA Headquarters, Code P-2, NASA TV, Washington, DC 20546-0001
Phone: (202) 358-3572
Home Page: http://www.hq.nasa.gov/office/pao/ntv.html

For more information about the Education Satellite Videoconference Series, contact: Videoconference Producer, NASA Teaching From Space Program, 308 CITD, Room A, Oklahoma State University, Stillwater, OK 74078-8089
E-mail: edge@aesp.nasa.okstate.edu
Home Page: http://www.okstate.edu/aesp/VC.html

How to Access NASA's Education Materials and Services, EP-1996-11-345-HQ This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the TRC network, or electronically via NASA Spacelink.

To follow SOHO's progress and to find links to other solar sites, please visit our web sites at: http://sohowww.nascom.nasa.gov/ and http://sohowww.nascom.nasa.gov/explore/

You can E-mail us at *letters@sohops.gsfc.nasa.gov*, or write us at: Explore, Code 682.3, NASA/GSFC, Greenbelt, MD 20771.